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Features Potential Measurements in Submicron High Integral Circuits Structures Using Electro-Optical Effect in Liquid Crystals

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The quantitative values of electric potentials in the elements of submicron structures High Integral Circuits in the operating mode can be experimentally determined using electro-optic effect in nematics liquid crystal. This method relates to methods of diagnosing electronic structures of High Integral Circuits using Technical System and relates to the technology of Automated Design System and High Integral Circuits.

Keywords: liquid crystals, highly integrated circuit, automated design system, nematic liquid crystals, twist-effect.

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Introduction

Liquid crystals (LC) are matter in a state which has properties between those of conventional liquids and those of solid crystals. For instance, a liquid crystal may flow like a liquid, but its molecules may be oriented in a crystal-like way. There are many different types of liquid-crystal phases, which can be distinguished by their different optical properties (such as birefringence). When viewed under a microscope using a polarized light source, different liquid crystal phases will appear to have distinct textures. The contrasting areas in the textures correspond to domains where the liquid-crystal molecules are oriented in different directions. Within a domain, however, the molecules are well ordered. LC materials may not always be in a liquid-crystal phase (just as water may turn into ice or steam).

Examples of liquid crystals can be found both in the natural world and in technological applications. Most contemporary electronic displays use liquid crystals. Lyotropic liquid-crystalline phases are abundant in living systems but can also be found in the mineral world. For example, many proteins and cell membranes are liquid crystals. Other well-known examples of liquid crystals are solutions of soap and various related detergents, as well as the tobacco mosaic virus, and some clays.

I. Features LC(Liquid crystals)

Liquid crystals - organic matter is that having basic properties of fluids - yield stress, retains a certain orderliness in the relative position of molecules and anisotropy of certain properties characteristic of crystals. The main feature of a liquid crystal state of matter molecules are expressed relative to the total directivity axis. Due to the anisotropy of the LC (Liquid Crystals) have interesting optical properties. Temperature interval of existence liquid crystal phase may be several factors. In the LC (Liquid Crystals) molecules are elongated, most cigar shape is what it determined certain prevailing orientation It is from the orientation of the molecules that some physical properties of the LC (Liquid Crystals) depend, in particular, the dielectric constant ε and the refractive index n. [4].

Depending on the degree of ordering of molecules distinguish three types (mesophase) LC (Liquid Crystals):

– Smectic when molecules are placed in pairs, and their longitudinal axes are parallel to each other;

– Nematic, where the molecules are parallel to each other, but offset along their longitudinal axes to the far distance, and layered structure is absent;

– Holistic when repeated structure of nematic crystals, but the vector direction changes in a spiral that is characterized by the quantum structure of LC (Liquid Crystals).

Thus, the main property of LC (Liquid Crystals), due to which it is possible to use as a thermal element for the use of the potentials of the LC (Liquid Crystals) elements of the submicron structures of the HIC (High Integral Circuits), is the ability to organize molecules in the external electric circle and to change the polarization and the phase of passing light. The main electro-optical effects in the LC (Liquid Crystals) are the dynamic scattering of light and the controlled rotation of the polarization plane in the twisted structure as a twist-effect. The most used in practice is the LC (Liquid Crystals) of a large type. In reproduction devices of the nematic type, which use dynamic scattering of light in the LC (Liquid Crystals), in the absence of an electric field is transparent, that is, it completely passes the incident light without dissipating it. In the case when the regular LC (Liquid Crystals) device is constantly or low-frequency voltage (tens of hertz) voltage, in the LC (Liquid Crystals) there is an optoelectric effect of dynamic scattering, in which the molecules are oriented and their dipole moment behind the field. In such a state, LC (Liquid Crystals) becomes turbulent and non-transparent (diffusion-dispersed), gaining milk-white parameter. For the realization of the optoelectric effect of dynamic scattering, the electric field strength in the LC (Liquid Crystals) should be about 5 eV/cm. For example, for a thickness of LC (Liquid Crystals) 12 mm, it is necessary to apply a voltage of 5 - 50 V. The speed of the LC (Liquid Crystals) cell depends on the chemical composition of the LC (Liquid Crystals) the intensity of the additives that reduce visibility (because the cholestic additive in the LC (Liquid Crystals) nematic type reduces the time of triggering), temperature, amplitude and frequency of control voltage. The second feature of the nematic LC (Liquid Crystals) is the orientation of their molecules in parallel to the microchannel on the surface of the conductive coating applied to the circuit and another substrate [1].

If the strong substrates of the LC cell turn one relative to the other on $^{\pi}/_{2}$, then in the LC the orientation of its molecules gradually changes from one plate to the other. Indirect polarization of light during its passage through a thin device of the LC also changes with the screw-like structure of the LC (Liquid Crystals) molecules by on $^{\pi}/_{2}$. And when applied to the electric field, the molecules of the LC (Liquid Crystals) will be calculated as a screw, the so called twist-effect and oriented in the direction of its vector of tension (Figure 1, a). Figure 1b illustrates the mechanism of a twist-effect in a nematic LC (Liquid Crystals) and the presence of an electric field. The molecules of the LC (Liquid Crystals) have a certain dipole moment. As a result of the interaction of electric fields in a dipole, a spiral structure is formed from molecules of a liquid crystalline substance (nematic). The layers of the orienting moments on the upper and lower substrates, in conjunction with the dipole structure of the LC (Liquid Crystals), in the absence of an electric field, provide the formation of a plane of polarization of the light flux on $^{\pi}/_{2}$. As can be seen from Figure 1b, the light signal flow disappeared through the upper polarized filter (polarizer) [4].

At the same time, half of the light flux, which does not have azimuthal polarization, is lost. In the remnants of parts of already polarized light that passes through the layer of liquid crystal material, the polarization plane returns to $^{\pi}/_{2}$. As a result, the orientation of the polarization planes of the lower filter and the flow will pass through it virtually without loss. If the LC (Liquid Crystals) is placed in an electric field, applying the voltage to the addressing electrodes as shown in Figure 1б b), because the spiral molecular structure in it will collapse. Then, through the liquid crystal material, the light flux will no longer change the plane of polarization and is almost completely absorbed by the lower polarized filter. The threshold voltage at which the light transmittance begins to decrease is about $U_a = 1,6 - 1,8$ V. Accordingly, LC (Liquid Crystals)(nematic) has two optical states: transparent and non-transparent. And the ratio of passage processes in both states determines the contrast of the image. At parallel axes of polarization of films of polarizers there is already an inverse effect. Thus, the LC (Liquid Crystals) cell is optically represented by an electric filter (other than an electron-optical modulator) and needs an external illumination.[4]

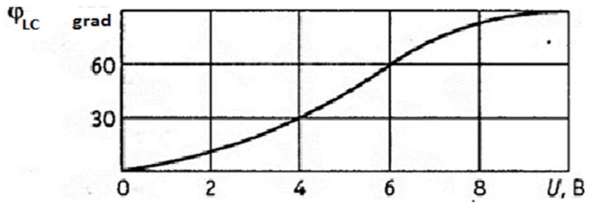

Fig. 1, a. The dependence of the angle of rotation of the polarization plane on the voltage on the electrodes of the liquid crystal cell.

II. Experiment technique

Measurement of electrical potentials of sub-micron structures of the HIC(High Integral Circuits).

Quantitative values of the electrical potentials of the HIC (High Integral Circuits) elements in the working mode, as well as in the actual contrast, can be determined by the electro-optical effect in the nematic LC (Liquid Crystals), the properties of which were considered in section 1. The electro-optical effects in nematic liquid crystals (LC) due to the interaction of the visco-elastic forces, the orientation action of the substrate

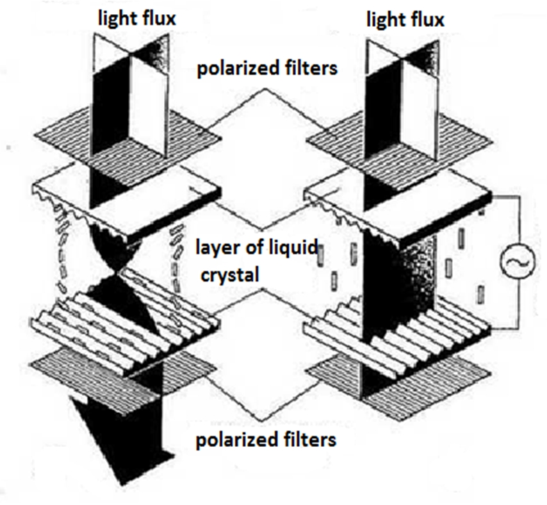

Fig. 1, b. Illustration explaining the mechanism of a twist-effect in nematic LC (Liquid Crystals).

and the excited field, are the nature of the thresholds. For typical NLC (Nematic Liguid Crystals), the threshold voltage U_n is in interval 1-8 V and is determined by the following formula:

$$U_n = \pi\sqrt{\frac{4\pi R}{|\Delta\varepsilon|}}$$

where R- is the twist-effect coefficient of elasticity, $\Delta\varepsilon$ – is the anisotropy of dielectric insensitivity.

The threshold or quantitative nature of the electron-optical effect in the NLC (Nematic Liguid Crystals) can be diagnostically used to determine the quantitative characteristics and parameters of the HIC (High Integral Circuits)structure, including semiconductor devices in the industry for schematic analysis, and for their electrophysical diagnostics of reliability. The most important is the use of NLC (Nematic Liguid Crystals) to determine the quantitative characteristics of the voltage of significant electrical potentials (apparently phonograms) on the elements and nodes of the operating HIC (High Integral Circuits)structures (especially sub-microns) when modeling their parameters. Already within the framework of the test control, attempts were made to use electro-optical effects in the NLC(Nematic Liquid Crystals) to obtain not only a qualitative picture of the distribution of electrical potentials, like the voltage contrast, but also for their quantitative values of the signal ADS (Automated Design System). For example, if on the surface of the crystal structures of the HIC (High Integral Circuits) to apply an oriented layer of LC (Liquid Crystals), and then apply the voltage to the structure of the HIC (High Integral Circuits), then under the action of the surface electric field in the layer of the LC (Liquid Crystals) will disappear changes in the initial orientation and birefringence, which can already be observed in the polarized light of the microscope. By comparing the visual images of the reorientation of the LC (Liquid Crystals) to the research and the reference test structure, one can promptly analyze the electrical modes of the HIC (High Integral Circuits) structure and obtain information on the causes of its defect. However, this method did not allow determining the quantitative values of electrical potentials of HIC (High Integral Circuits) elements and nodes.

The magnitude of potential structures on the surface of HIC (High Integral Circuits) can be judged from the brightness of light cast LC (Liquid Crystals) layer over remote regions of topological scheme. However, this method only determined electric potentials on areas HIC (High Integral Circuits) structure over which is the reorientation of the NLC (Nematic Liguid Crystals) under its own electric field over the surface included in the power mode crystal structure HIC (High Integral Circuits) , while it is necessary that the electric field of the specified regions reached a certain value. If its value is less than this value, then the electrical potentials do not appear. This method is quite labor-intensive in the field of optical information and does not provide the necessary accuracy of their fixation.

This measurement option is also possible [5]. On the surface of the investigation of the HIC structures, an oriented NLC (Nematic Liguid Crystals) - layer applied by a plate with a transparent conductive layer In_2O_3 та $6SnO_2$ is drawn to the NLC (Nematic Liguid Crystals). When the HIC (High Integral Circuits) circuit is released to the operating mode, a test voltage is applied to a transparent conductive layer with a strong substrate. In this case, over certain regions of the structure of the HIC (High Integral Circuits) in the NLC (Nematic Liguid Crystals) arise under the action of the electric field of birefringence, which in polarized light manifests itself in the form of an optical topological pattern, that is, they determine the regions of circuits with the same potential - that is, to fix the logical image - the state of the scheme. However, this method can be not accurately determine the values of potentials (complex amplitudes), whose values are particularly important for signal ADS (Automated Design System). For the determined quantitative values of the electric potentials of the cast elements and the topological areas of the WSI structures, the voltage filtrate (potential) is transmitted over the transparent conductive layer of the substrate at the moment of reorientation of the NLC (Nematic Liguid Crystals) over the analytical region of the HIC (High Integral Circuits) topological circuit [4].

The reorientation of the NLC (Nematic Liguid Crystals) takes place more when the primary voltage is reached between the transparent electrode and the exploration region of the topological circuit of the value of the reorientation threshold U_a. In other words, if φ_k is the potential on the nominal area of the topological circuit, and φ_n- potential in the transparent emerald, then the reorientation proceeds under the condition $\varphi_n - \varphi_k \geq U_n$ or $\varphi_k - \varphi_n \geq \varphi_k$. At the start of the reorientation process, $\varphi_k = \varphi_n - U_n$. For a given type of NLC (Nematic Liguid Crystals) there is always a known threshold voltage U_n. In the case of fixed φ_n (at the moment of reorientation) in place $\varphi_k = \varphi_a - U_n$.

The scheme of implementation of the proposed method is shown in Figure 2, a.

Thus, the fixation of the value of the monotonically changing voltage over a transparent electrodes electrode at the moment of reorientation of the NLC (Nematic Liguid Crystals)over the topological domain of the HIC structure (node elements) allows us to use the universal

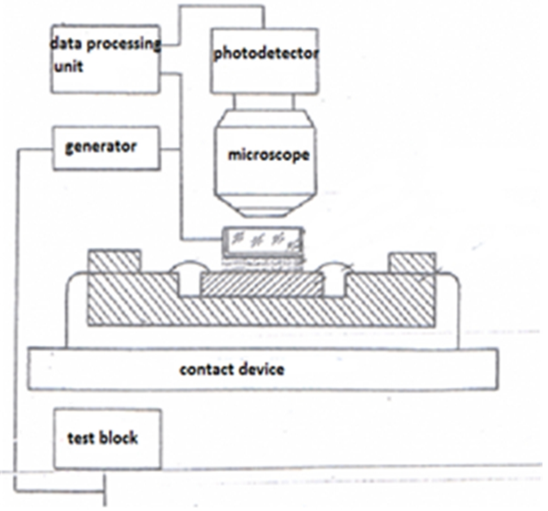

Fig. 2, a. Scheme for measuring electrical potentials.

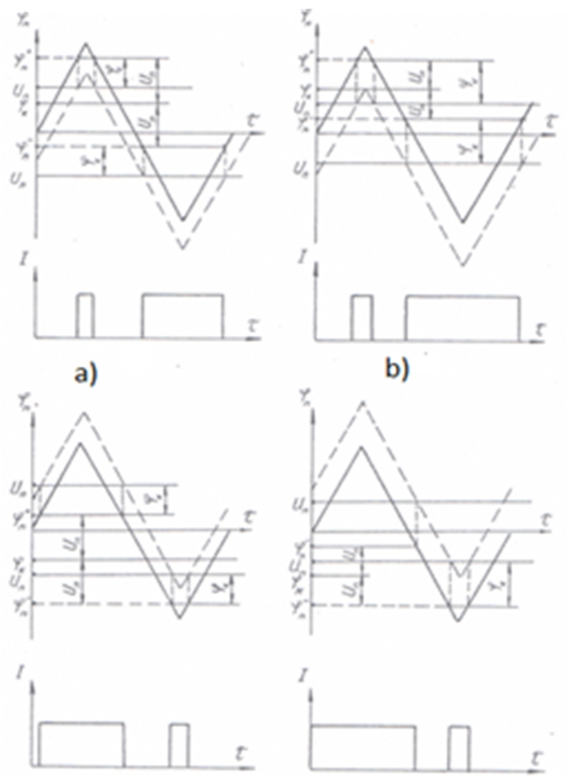

Fig. 2, b. The capacitance measurement diagrams (φ) on the transparent electrode (continuous line), the difference $\varphi_{\text{п}} - \varphi_{\text{к}}$ (dotted line) and the brightness for $|U_{\text{п}}| > \varphi_{\text{к}}$, a) $|U_{\text{п}}| < \varphi_{\text{к}}$, b) for $\varphi_{\text{к}} > 0$ and $|U_{\text{п}}||>|\varphi_{\text{к}}$, c) $|U_{\text{п}}||<|\varphi_{\text{к}}$ for $\varphi_{\text{к}} < 0$.

value of the threshold voltage U_n of the NLC (Nematic Liguid Crystals) reorientation to determine the complex amplitude (phase) potential in any area of the HIC (High Integral Circuits circuit.[5]

The structure of the HIC (High Integral Circuits) is installed in the contact device - the probe table. On its surface is applied a layer of oriented, for example, with crossed paperweights translates into reflected polarized light. Using the test block, a given power supply mode of the HIC (High Integral Circuits)structure is given, which determines the qualitative and quantitative distribution of electrical potentials on the crystal surface of the HIC (High Integral Circuits)structure. And the generator supplies a periodic signal to the transparent conducting electrode, for example a triangular shape.

The corresponding voltage change diagrams in time τ, set on the transparent electrodelectrodide potential φ_n the difference $(\varphi_n - \varphi_k)$and brightness are shown in Figure 2, b. Potentials φ_n on a transparent conductive electrode, which attained a reorientation of the NLC (Nematic Liguid Crystals) in the diagrams in Figure 2b, marked, respectively, φ_n^+- the potential for initiation of the reorientation of the NLC (Nematic Liguid Crystals) with positive potential on a transparent electrode and φ_n^-- with a negative one. The potential on the investigated element (nodes) of the HIC (High Integral Circuits) structure is defined as follows: $\varphi_k = \varphi_n^+ - U_n$; $\varphi_k = \varphi_a^- - U_a$;

In this case, if $\varphi_k$is defined in the region of positive values of the φ_n diagram, then use U_n with a "+" sign, and if in the field negative values φ_n always satisfy condition: $\varphi_k > 0$, if $|\varphi_n^-| < |\varphi_n^+|$ and if $|\varphi_n^-| > \varphi_n^+$. For example, let the NLC (Nematic Liguid Crystals) reorientation U_n=± 4.5B, and the measured potential of the beginning of the reorientation of the NLC (Nematic Liguid Crystals) in the region of positive values φ_n^+=6B , and in the region of the discrete values of φ_n^-= -3B then $\varphi_k = \varphi_n^+ - U_n = 6 - 4.5 = 1.5$, if $\varphi_k = \varphi_n^- - U_n = -3 - (-4.5) = 1.5$B .

At the moment, which corresponds to the beginning of the reorientation of the HIC (High Integral Circuits), the brightness of the reflected NLC layer of light changes. The fixation of the moment of reorientation of the NLC is carried out with the help of a photodetector. Then the electrical signal from the photodetector is transmitted to the data processing base. Here also comes the electric signal from the generator. The data processing base requires a differentiating link, a comparison scheme, a memory register, and a schema of outputting data on the display board. In the reorientation of the NLC in the photodetector there is a step of the current, which also plays the role of the sync pulse for registering data in the memory register of the data processing unit. At the same time, the value of φ_n, corresponding to the moment of reorientation, is memorized in the memory register. Using different methods and comparison schemes, define the module and the sign φ_k obtained as a biasing (left or right) of the value φ_n and the value U_n, which is entered into the processing unit as a constant value. The scheme of outputting the data of the formulas of the signal on the display board, which illuminates the sign and the magnitude of the potential of the analyzing area of the element or the input structure of the HIC (High Integral Circuits).[2].

As shown in the diagrams (Figure 2, b), the sign of the determined value φ_k of the analyzing region of the region of the topological structure of the HIC can be compared with the duration and sequence of the pulses of light in the process of changing the value of φ_n. If at first (with $\varphi_n > 0$), then a shorter pulse of light shines than the next ($\varphi_n < 0$), then φ_k> 0. If at first ($\varphi_n > 0$) there passes a longer pulse of luminescence than the next with ($\varphi_n < 0$), then we obtain $\varphi_k < 0$.

The received diagrammatic picture of the distribution of electric potentials on the topological structure of the HIC allows to analyze areas with abnormal potentials, to conduct an analysis and to find out the reasons for their occurrence.

Determination and analysis of the distribution of electrical potentials of the investigated structures HIC (High Integral Circuits)allows to develop technical recommendations for the improvement of the scheme of technical, technological, topological or functional solutions in the design of structures HIC (High Integral Circuits), as well as in the process of their serial production in order to increase the availability of suitable and reliability diagnostics.

Threshold nature of the reorientation of the NLC allows to determine also the quantitative characteristics of the electrical properties of semiconductor structures HIC (High Integral Circuits). The local significance of resistivity and conductivity of different functional layers, the magnitude of current losses due to the dielectric isolation of the pockets, the electrical properties of dielectrics and the magnitude of the current losses through them, the threshold stresses of parasitic transistors (acts as a test method in technological ADS (Automated Design System)). The quantitative value of the conductivity of the specific resistance of the screw dielectric and the currents of loss through it in the semiconductor structures HIC (High Integral Circuits) is determined with the help of existing electrophysical control. The plate from the gate insulator, in which the aluminum alloying sites are applied to the entire width, are installed in the NLC-cassette. A transparent electrode is monotonously fed by a growing voltage, and its value is fixed, at which a reorientation of the NLC (Nematic Liguid Crystals)begins to occur, observing us with aluminum vessels.

If the reorientation is achieved at a potential difference between the plate and the transparent electrode (TE), which is equal to the pow voltage, because such areas become frozen on the substrate. If this voltage U is greater than the threshold U_n, then $U-U_n$-voltage is applied to the dielectric, and its value expresses the degree of current losses through the diameters with an area equal to the aluminum. (from the relation $\frac{U-U_n}{U_n}=\frac{\rho_d\delta_\alpha}{\rho_{pk}\delta_{pk}}$, where $\rho_d\delta_\alpha$- is the characteristic impedance and dielectric thickness, $\rho_{pk}\delta_{pk}$ is the specific resistance and the thickness of the LCD layer), the following conclusion can be made.

Since the value $\delta\delta_\alpha\rho_{pk}\delta_{pk}$ is most often seen from the technology and can be measured, it is easy to determine $\rho_d$under aluminum metallization here. The aggregate of such data in all aluminum plates on the plate substrate gives a picture of the distribution ρ_d in the area of the plate. The loss current through the closure dielectric when the NLC reorientates over the aluminum plate is determined by the formula $I_{loss}=\frac{U_n S_{al}}{\rho_{pk}\delta_{pk}}$ where S_{al} is the area of the aluminum plate. That is, you can locally determine any electrophysical parameters of test control.

III. Results and their discussion

Use of NLC to remove the temperature field of HIC crystal structures.

The most frequent types of refusals HIC (High Integral Circuits) are characterized by the release of heat in the local areas of their structure. Therefore, the study of the temperature fields of the WSI structure allows qualitative detection of the defect and electrophysical diagnostics.

There are several ways to register a temperature field HIC (High Integral Circuits). The most common method is to obtain a thermo-dependent color picture of the liquid crystal phase in cholesteric LC, and in infrared radiometry. However, the resolution of these methods is not sufficient to study defects in modern low-power and with a large degree of integration HIC (High Integral Circuits). It is precisely the method based on the phase transition in nematic liquid crystals (NLC) that allows for a high separation and sensitivity than infrared radiometry and the method of CRC. This is due to the fact that the temperature difference of the phase transition in the NLC is very small (0.01 °) and is clearly fixed with a microscope, complete with polarizers. It is the NLC characterized by birefringence and, therefore, in the crossed polaroid film NLC, which is applied to the surface of the structure HIC (High Integral Circuits)looks like a bright field.

If the temperature of the surface of the structure (which is formed by an external heater) is raised, then in local areas where it begins to exceed the value of the phase transition of the NLC to an isotropic liquid, the birefringence disappears and these places already look like black spots. At the edge of the black spot, the temperature of the surface is equal to the temperature of the phase transition. On this effect, the definition of the temperature of the surface of the structure of the HIC (High Integral Circuits) is based.

The method of forming a heat-resistant multilayer metallization of the upper level of the wiring of structures of highly integrated circuits, which includes the formation of structures with profile levels in interlayer metallization using a photolithographic process. [3]

In experiments, the structure is studied the HIC (High Integral Circuits) is installed in contact devices - cryostatin table. The overheating of the surface of the WSI structure to a temperature close to the temperature of the mesophase of the NLC can be accomplished with the help of an external heater installed in the contact device. As a heater, a tantalum thin film resistor may be used on a sylindrical substrate. Thermostat allows to remove maps of temperature distribution along the surface of the structure | C | HIC The source of heat can be diffusion resistors or transistors [4].

In Figure 3, a photo of a test structure with a layer of NLC (Nematic Liguid Crystals) is presented. The dark spot in the center of the resistor is the LC, which is already in the isotropic phase.

Upon reaching the structure HIC (High Integral Circuits) by the method of the NLC (Nematic Liguid

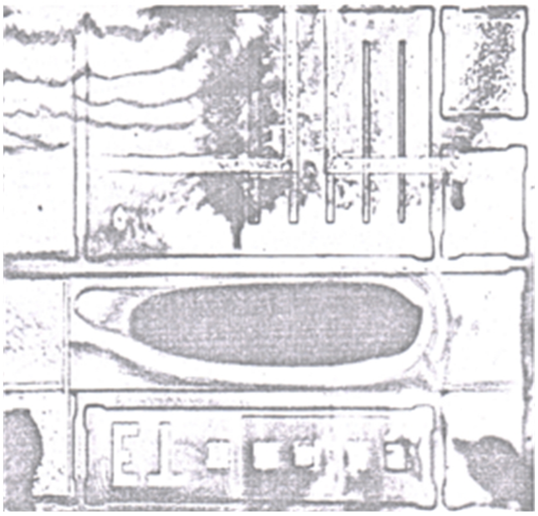

Fig. 3. Test stack with a layer of LC.

Crystals) probe is most often used by the electric field effect, based on the homogeneous orientation of NLC molecules in the gap between the surface of the probe and the surface of the structure HIC (High

Integral Circuits) when moving the microscope table, the NLC(Nematic Liguid Crystals) layer, which is in the gap between the lower surface and the surface of the structure, is moved, and its orientation is practically without delay in a certain place.[5]

For electrophysical diagnostics by the NLC method, a microscope MMU-11 "Epival" is used, with the NLC probe prefixes that are similar in design. At the prefixes to microscopes MMU-11 and "Epival" the corresponding design documentation was developed 920.E2.00s and 920. E1 00sb. Formed NLC probes used to diagnose structures | C | HIC, include the following submicron technology ADS (Automated Design System):

- determination of the quality of the passive layer of the or Al_2O_3over the metallized layers;
- control of electric contact of contact pads in a crystal;
- control of the electrical contact of metallized crystals with the topological links of the contact pads of the crystal;
- determination of quantitative values of electrical potentials of elements and nodes on the surface of the ADS (Automated Design System) structure.
- control and diagnostics of the quality of the insulated, between the ball, under the shutter and the thin oxide and the opening of the metal windows;
- control of the distribution of the temperature field on the vertices of structures;
- quality control of pocket insulation and insulating oxidative HIC on the basis oftructures;
- evaluation of the thickness of the dielectric layer on the conductive substrate;
- quality control between layer insulator .
- control and diagnostics for a closure dielectric in High Integral Circuits with polypropylene shutter;
- formation of test cells for arbostat-table of probe measurements.

Used in NLC probe prefixes to microscope MMU-11, variable probes, which are cylinders with a surface coated with a transparent conductive film SaO_2, have a diameter of 0.5-1.5 and a length of 2 and 3 mm. NLC probe prefabricated to the microscopes are convenient for operation, tuning, reliably provide contact with electrically controlled transparent electrode and completely eliminate the possibility of destruction of the wire leads of the crystal and their shortening to the probes, that is, the NLC prefix is universal for different structures of ADS technology.

Conclusions

1. Analyzed electro effects in liquid crystals and envisage their use in SAPR technology.
2. The method of measuring the electrical potential on the surface structure of the LC (Liquid Crystals) using electro twist effect in NLC (Nematic Liguid Crystals)
3. Method of removing exhaust temperature field on the surface of the transparent structure LC to determine the areas of local warming.
4. Developed attachment to microscopes MMU-11 and «Epival» for electrodiagnostics using NLC probes.
5. Designed for ADS(Automated Design System) technology methods electrophysical diagnostics reliability of HIC(High Integral Circuits) structures by NLC.

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Особливості вимірювання потенціалів в субмікронних структурах ВІС з використанням електрооптичного ефекту в рідких кристалах

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Кількісні значення електричного потенціалу генерування елементів субмікронних структур ВІС в робочому режимі можуть бути експериментально визначені електрооптичним ефектом в нематичному рідкому кристалі. Цей метод стосується методів електронної діагностики структур ВІС, що використовують ТК, і відноситься до САПР системи ВІС.

Ключові слова: рідкі кристали, високоінтегральний контур, автоматизована система проектування, нематичні рідкі кристали, твіст-ефект.